

## Referee report

**In the competition for academic position “Associate professor” in the professional field Physical sciences (string theory and high energy physics) for the needs of Sofia University “St. Kliment Ohridski” (SU), Faculty of Physics (FzF), announced in State Gazette no. 63 from 30.07.2021.**

The report is written by associate professor **Kiril Petrov Hristov**, Ph.D., member of the **Physical sciences (string theory and high energy physics)** jury, in accordance with order RD-38-488/01.20.2021 of the rector of Sofia University.

Senior assistant professor **Tsvetan Ivanov Vetsov**, Ph.D., from Sofia University, is the only applicant.

### **I. General description of the submitted materials**

#### **1. Application data**

The documents submitted for the competition by the candidate comply with the requirements of ZRASRB, PPZRASRB and the Regulations on the terms and conditions for acquiring scientific degrees and academic positions at Sofia University "St. Kliment Ohridski "(PURPNSZADSU). For participation in the competition, the candidate Tsvetan Ivanov Vetsov submitted a list of a total of 18 titles, including 17 publications in foreign scientific journals, and 1 chapter in a scientific book. 24 other documents are also presented, described in detail in the Application of the candidate for admission to the competition and supporting the achievements of the candidate.

The applicant has submitted all required documents according to ZRASRB, PPZRASRB and PURPNSZADSU.

#### **2. Applicant's data**

The candidate is born in August 2986 in Razlog. He received a bachelor's degree in physics (2009) and master's degree in theoretical and mathematical physics (2011) in FzF of SU. The master thesis of Tsvetan is under the supervision of Professor Radoslav Rashkov, on the topic of “Semiclassical calculation of three-point correlation functions in  $AdS_5 \times S^5$ ”. The candidate defends his Ph.D. thesis “Stringy approach to gauge theories” in 2015 under the same supervision. From 2015 to this day the candidate is senior assistant professor in the Theoretical physics group in FzF of SU. During these years Tsvetan teaches numerous lectures and tutorials in various FzF courses in mathematics and physics. He acted as a student advisor on the the bachelor thesis projects “Aharonov-Bohm effect in non-commutative space,” “Yang-Mills theories and Aharonov-Bohm effect,” and “Generalized electrodynamics of Podolsky”.

The candidate took part (also with talks) in many international conferences and workshops, he participated in many national science projects and organized an international Ph.D. school in Sofia in 2017.

### **3. Scientific publications and achievements of the applicant**

The scientific activity of the candidate is focused on modern topics of theoretical and mathematical physics, including string theory, that fits exactly into the criteria of the present competition.

In more detail, the scientific output can be divided in several interconnected topics, generally related to the theories of bosonic and super strings, holography, information theory, and the general theory of relativity. The concrete contributions of Tsvetan are related to:

- Solutions of string theory and their properties, including solutions for spiky strings and magnons, and supergravity solutions using non-abelian T-duality.
- Information geometry and entanglement entropy, including relations to the holographic duality and string theory.
- Thermodynamics of black holes and solutions of accretion disks around dark compact objects in different relativistic theories (not always motivated by string theory)

For the present competition the candidate presented a total of 23 publications, 18 of them concretely for the position of “associate professor”. The candidate gathers the following points: 50 in group A, 125 in group C, 247 in group D, 166 in group E and 225 in group F. In addition, the number of advised bachelor students, the number of publications in the last year, the h-factor and the number of teaching hours all exceed the additional required criteria in SU and thus fulfill them.

In conclusion I can firmly confirm that:

(a) the minimal requirements of ZRASRB, PPZRASRB and the additional requirements of SU for the academic position “associate professor” are satisfied.

(b) the scientific publications do not coincide with publications used in previous competitions of the applicant. In his case, for his PhD thesis and for the academic position “senior assistant professor”;

(c) There is no plagiarism in his publications

### **4. Teaching experience of the applicant**

The applicant has a considerable teaching experience, including lectures in mathematical analysis of functions, vectors and tensors, and quantum field theory, as well as tutorials on these subjects and on electrodynamics and theoretical mechanics. This is a wide spectrum of courses, giving a very good pedagogical experience, and is much above the minimal requirements.

## 5. Detailed scientific analysis of applicant's scientific achievements

The nature of candidate's scientific output can be generally categorized as deducing new scientific facts and using new tools for enriching the existing systems of knowledge, concretely in the area of string theory, the holographic duality and the general theory of relativity.

Separating the various contributions thematically, the achievements of the candidate include:

- Spiky and pulsating strings and magnons (articles [11,12,13] and [17]) – Tsvetan considered new types of semiclassical string solutions, contributing to new examples of holographic duality. Some of the main results include finding the equations of motion of the strings and the calculation of the anomalous dimensions of the holographically dual operators, as well as the calculation of the three-point correlators between two heavy and one light operators.
- Non-abelian T-duality (articles [10,20]) – new types of supergravity backgrounds have been found using the non-abelian T-duality in string theory. Contrary to the better known case of abelian T-duality, the non-abelian case is not yet known to follow standard rules. Tsvetan helps in the explicit realization of this transformation for the special case of the Pilch-Warner background.
- Information geometry and the Fisher metric (articles [6,7,8,9,14,18,19,21,22]) – in a series of articles Tsvetan and collaborators consider the information geometry, coming originally from statistical considerations in information theory. These tools were applied on a series of interesting physical systems, including black holes and stringy solutions with holographic applications. This presents a novel direction in theoretical physics with a lot of potential for future development. In [6] Tsvetan considered the DST black holes in modified 4d gravity with non-polynomial higher derivative corrections, resulting in a modification of the first law of thermodynamics. In [7,22] they considered a black hole in 3d massive topological gravity, investigating the conditions for local and global thermodynamic stability and the consequences for the information geometry. Another 3d black hole, of Lifshitz type, was considered in [8]. In [9] and [21] the Fisher metric was calculated for the case of bosonic strings on plane wave background, an example for integrable structure. In [14,18,21] they also considered Pais-Uhlenbeck oscillators. In [19] they considered the Fisher metric in a system with non-relativistic symmetries, coming from the Schroedinger spacetime that drives the development of non-relativistic holography.
- Black hole thermodynamics (articles [6,8,23]) – related to the previous topic, thermodynamics is one of the defining properties of black holes as a statistical gravitational system, considered by Tsvetan and collaborators in a series of articles. In [6] he considered the 4d DST black hole in modified gravity with non-polynomial higher derivative corrections, leading to a modification of the first law of thermodynamics. Using the Brown-York method, he also derived the black hole mass in the same work. In [8] they considered a 3d black hole was again considered in a higher derivative gravity. In this case they derived the Smarr relations between thermodynamic variables, as well as the higher derivative corrections to the entropy.

- Entanglement entropy (articles [9, 14]) – entanglement entropy is an important quantum property of systems, which in this case was considered in several specific string theory inspired systems. In [9] they considered the bosonic string in plane wave background, where they found the reduced density matrix and analyzed it in various spatial dimensions. In the same article they calculated the entanglement entropy of different bosonic and fermionic systems with condensed matter applications. In [14] a similar results was derived for the Pais-Uhlenbeck oscillators.
- Solutions and analysis of black holes and dark compact objects of modified gravitational theories (articles [15,16]) – in a non-string theory inspired topic with a more immediate application in modern theoretical astrophysics, Tsvetan and collaborators studied via numerical simulations the relativistic images around black holes and naked singularities in modified theory of relativity.
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Most of the above described scientific works are a collaborative effort, mostly within FzF in SU. The results find a considerable application in scientific literature by other authors, with 157 independent citations according to the Inspire-HEP page, which is the most complete data base in the area of higher energy theoretical physics.

## **6. Critical remarks**

I have no critical remarks on the scientific aspect of the publications or the chosen topics. My only remark concerns the lack of scientific mobility, given that Tsvetan has spent all his student and research years so far at the same place, working mostly with collaborators that are immediately close to him. In his case (see below) this did not prevent the candidate from having a variety of scientific interests, but my recommendation to him is to travel more often abroad and make a conscious effort to initiate scientific collaborations outside of FzF in SU.

## **7. Personal impression**

One of the first impressions that Tsvetan leaves after a personal acquaintance is his big passion and enthusiasm for physics. He is always ready to spend time in discussions on new physics ideas and problems, as well as to explain his own ideas to the interested students. I think that his activity and interest in various parts of physics are very important for the creation of a nice collaborative atmosphere in the theoretical physics group in FzF. In this sense the candidate is already an integral part of the group and this academic step up is coming right on time. In addition, Tsvetan has proven his leading role in many successful collaborations and is fully capable of giving scientific tasks to bachelor and PhD students, as well as finding original solutions to such tasks himself.

## 8. Conclusion for the applicant

After I got acquainted with all documents submitted for this competition and on the basis of the analysis of the latter importance and their scientific achievements I **confirm** that the scientific contributions fully comply with the requirements of the Law for advancement of the academic staff in the Republic of Bulgaria and with its Regulations, as well as with the Additional Regulations of Sofia University “St. Kliment Ohridski for the candidate to be employed on the academic position “Associate Professor” in the scientific field and professional direction of this competition. I also confirm that the candidate fulfills the minimal requirements for this scientific field and professional direction and no plagiarism was found in his publications submitted for this competition.

I state my **positive** assessment.

## II. General conclusion

Based on the abovementioned, I **recommend** to the Scientific Jury to propose to the qualified selection body of the Faculty of Physics of Sofia University “St. Kliment Ohridski” to select **Tsvetan Ivanov Vetsov** for the academic position “Associate Professor” in the professional field 4.1 Physical Sciences (Theoretical and Mathematical Physics).

19.11.2021

Referee:

Assoc. Prof. Kiril Petrov Hristov